Power Aware Routing in Ad Hoc Networks

Power Aware Routing - by S. Singh et al.
Roadmap

- Objective/Motivation
- Related work and why it does not suffice.
- The new power aware metrics introduced in the paper.
- Overview of PAMAS a power aware MAC
- What do they find?
Motivation/Objectives

- Typical routing protocols that use shortest path tend to drain specific nodes of battery resources.
- The depletion of energy leads to node failures.
- Routes through nodes that could be potentially longer but are through nodes with large energy reserves.
- Routing through lightly loaded nodes - energy expended in contention is minimized.
Routing Protocols and Energy: Related Work

- Energy expended due to control message transmissions.
- Two conflicting goals – keep track of frequent topology changes versus reducing message overhead.
- On-Demand versus Table Driven – an issue with scalability.
- Refer to paper and think about the power efficiency of the various protocols – refer table in reference [4].
New Metrics --- I

- Minimize the energy consumed in transmitting (and receiving) a packet.
- Take into account energy consumed due to coping with contention effects.
- In light loads this results in shortest path.
- Does not take into account residual power at nodes.
- Could lead to the early demise of certain nodes.
An Example

• Node 6 is likely to fail due to battery drainage since the three flows all go through 6.
New Metrics -- II

• Maximize the time to network partition (Hard problem).
• Identify those nodes whose death could lead to network partitions.
• Use of the Max-flow Min-Cut theorem.
• Computing the min-cut gives the relative importance of the nodes.
• These nodes should be “saved” by routing around them to the extent possible.
• In some sense similar to load balancing as in Case I.
New Metrics --- III

- Minimize Variance in Node Power Levels
- Intuition: All nodes are equally important and we should not penalize certain nodes.
- Similar to load sharing in distributed systems.
- Fill queues equally to the extent possible.
- Choose the neighbor whose queue is least filled.
New Metric --- IV

• Minimize Cost/Packet - We want to minimize the energy consumed per packet.

• Let $f_i(x_i)$ denote the node cost; $x_i$ is the energy expended by the node thus far.

$$c_j = \sum_{i=0}^{j-1} f_i(x_i)$$

The goal of this metric is to:

Minimize $c_j$, $V$ packets $j$

Equation from [4].
• Choose $f_i$ so as to reflect a battery’s remaining lifetime.

• $f_i$ denotes the node’s burden in terms of forwarding packets.
Battery Behavior

- Discharge model for Lithium Ion battery from [4].
- Voltage tells you the capacity left.
- As voltage starts to dramatically drop, almost the end.
- Different for other batteries.
Knowing the voltage output by the battery, one can determine the residual lifetime - that would represent the function f for the node.

Use this as the weight of the node while computing the route.
New Metric --- V

- Minimize the maximum node cost after routing “N” (a system parameter) packets to their destinations or after “T” seconds.

- Again, the goal is to reduce the possibility of nodes failing.

- The authors only implement Metrics I and IV in their simulation studies.
PAMAS: Power-Aware Multiple Access Protocol with Signaling

• What does it do? → Enable nodes intelligently turn off their radios when they can neither transmit nor receive.

• Node C turns off radio when A is transmitting to B.

Figure from [4]
Conditions under which nodes power-off with PAMAS

• A node powers off if
  • It is overhearing a transmission and does not have a packet to transmit.
  • If at least one neighbor is transmitting and at least one neighbor is receiving. (it cannot transmit due to the interference it might cause at the receiving node).
  • If all of the node’s neighbors are transmitting.
How long should a node power off?

- In PAMAS RTS/CTS exchanged over a separate second control channel.
- The receiver starts sending a busy tone on the control channel - tells other neighbors of the ongoing reception.
- Based on the durations specified in the RTS/CTS messages, the nodes can deduce when to go silent.
Can Sleeping Dogs Lie?

- When nodes wake up from sleep how do they know how long to wait?
- They would need to estimate this.
- PAMAS includes a protocol that allows these "waking up" nodes to query transmitters for length of transmission on control channel.
- Collisions are handled using binary back-off.
- PAMAS achieves about 40-70% savings in terms of consumed power.
Performance Summary

• Larger networks – higher cost savings – more routes to choose from – can more evenly distribute power consumption.

• Denser networks – better performance – same reasons – more diversity.

• Cost function dramatically affects the performance – clearly the case – e.g. if battery life does not drain quickly, lower performance gains.
Performance Summary Continued: Variation with Load

• Best performance at moderate loads.

• At low loads not much gain in performance: Why?
  • Effects do not impact energy consumption much.

• At very high loads again not much gain in performance: Why?
  • There is not much you can do !!!!
To Conclude:

- These metrics can be incorporated for use with any of the traditional routing protocols that you read about.
- Lot of space left for project – can we compute min-cut to incorporate metrics that the authors mention but leave out.
- What is the impact of finding min-cut over localized topologies?
Signal Strength Adaptive Routing – Dube, Rais, Wang and Tripathi
Principle of SSA

- Select routes based on the signal strength between nodes and on a node’s location stability.
- Choose routes that have stronger connectivity.
- SSA has two component co-operative protocols:
  - The Dynamic Routing Protocol
  - The Static Routing Protocol.
The Dynamic Routing Protocol (DRP)

- The DRP is responsible for maintaining what is called the Signal Stability Table and also the Routing Table.
- SST - record of signal strengths of neighboring nodes which is obtained by means of periodic beaconing.
- Quantized levels possible → weak channel vs. strong channel.
- When a packet is received, DRP processes the packet, updates the tables and passes the received packet to the SRP.
The Static Routing Protocol (DRP)

- Forwards the packet up to the transport layer if it is the receiver.
- If not, it looks up the routing table and forwards the packet to the appropriate next-hop.
- If no entry is found, it initiates a route search.
The Route Search

- Route requests are propagated throughout the network – however ...

- Forwarded onto the next hop, only if they are received over “strong” channels” and have not yet been previously processed. /* Notice that the second condition prevents looping */.

- The destination chooses the first arriving query message because it is most probable that the packet arrived on the “strongest”, shortest and/or least congested path.

- DRP reverses the route and sends a route-reply back to the sender.
The PREF field

- Notice so far that a route-search packet is forwarded only if it arrived on a strong link.
- However, it is possible that no route is found with strong links all the way.
- At this time, the source initiates another route-search and uses what is called the “PREF” field to indicate that weak links are acceptable.
Route Maintenance

• Use a route error message to the source to indicate which channel has failed.

• Source then initiates a new route-search to find a new path to the destination.
How does SSA help conserve energy?

- Choice of stable routes minimizes route failures.
- This in turn reduces route re-computation overhead.
- Note that failures are expensive - TCP retransmissions.
- Also helps avoid congested regions - reduction in contention overhead.